

College Physics I

Lab 5: Simple Harmonic Motion

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Static determination of the spring constant k

The magnitude of the force an ideal spring exerts is proportional to its displacement from equilibrium, Δx . k is the proportionality constant.

One way to determine k for a spring is to hang a mass m from it. The force that mass is exerting on the spring is then mg , where g is the acceleration due to gravity—assume $g = 9.80 \text{ m/s}^2$. We can then see how far the spring stretches. More quantitatively:

$$\begin{aligned} |F| &= k|\Delta x|, \\ |F| &= mg, \\ \Rightarrow |\Delta x| &= \frac{g}{k}m. \end{aligned} \tag{1}$$

Thus if you graph $|\Delta x|$ versus m (with m on the horizontal axis), and the data approximate a straight line, that is evidence that the spring is close to ideal. Furthermore, the slope of the line, s , will be g/k . You could determine k if you found s : $k = g/s$.

Activity 1: Determine k

Using the method outlined above, find k . Use 10 different masses, but don't add more than 500 g total, as more than that may permanently deform the spring.

To hand in for activity 1

- Values of m and $|\Delta x|$ for each trial,
- Graph of $|\Delta x|$ versus m ,
- Calculation of s ,
- Final result for k .

When the spring is moving

The larger the spring constant k , the “stiffer” the spring—the constant k is often referred to as the *stiffness* of the spring. As it happens, T , the period of vibration of a mass m bouncing on a spring is

$$T = 2\pi\sqrt{\frac{m}{k}} \quad (2)$$

For a particular spring, k should be constant. Thus T is equal to a constant times \sqrt{m} , or equivalently, T^2 is proportional to m . Therefore, if you put a bunch of different masses on a spring and measure the period for each mass, and then graph T^2 versus m , you should get a straight line with a slope of $(2\pi)^2/k$:

$$T^2 = \left[\frac{(2\pi)^2}{k} \right] m \quad (3)$$

The most precise way to measure the period is to measure, say, 50 periods, and then divide by 50. That way, any imprecision in your measuring process is spread out over a much greater time, and will have a much smaller overall effect. If n is the number of periods you time, and t_n is the time for all those periods, then:

$$T = \frac{t_n}{n} \quad (4)$$

You will have to face an extra complication in this part of the lab. I want you to figure out a way of measuring time *without* using any watches, clocks, or other device that is designed to tell time. This is, in fact, a problem the first experimental physicists faced, before devices to measure short periods of time became available.

Activity 2: Period as a function of mass

Think of a method of measuring time intervals. Call your basic time interval τ , so that you will be measuring time in units of τ 's. Note that as long as τ is short (comparable to the period of the oscillations) and fairly constant, you will do fine. Just to check whether T^2 is proportional to m does not require that time be measured in any particular units, so don't worry if you can't tell exactly how many seconds τ happens to be.

Now, using your method of timing, find T for ten different values of hanging mass ranging from 50 g up to about 300 g. Then make a graph of T^2 versus amount of hanging mass, again with m on the horizontal axis. With an ideal spring, you should get a straight line. Do you?

In fact, if all went according to expectations, calculating the slope of the line in this graph should give you what τ is, in seconds. Use equation (3) to derive an expression relating your slope and τ . Then use this expression to calculate τ . (*Hint*: the units for your slope will include τ rather than seconds.)

You can then ask me for a stopwatch to measure τ directly. Keep in mind that due to human reaction time, a single measurement will not be very accurate.

To hand in for activity 2

- A description of your method of timing.
- Values of m , t_n , n , T and T^2 for each trial (time measured in τ 's).
- Graph of T^2 versus m , and the slope.
- The expression relating slope and τ in seconds.
- Your measurement for τ using a stopwatch.